N75 13767

Planetary Geology

APOLLO LANDING SITE EXERCISE

Ronald Greeley

INSTRUCTOR NOTES

1. This exercise enables the student to use the information gained in lunar geology toward the solution of a practical problem. To be effective, the exercise should be given toward the end of the course so that the students have sufficien' background in lunar geology.

Using reference materials for a *general* landing site (e.g., the crater Copernicus), a specific landing site is to be selected and geological traverses planned.

2. The exercise can be handled several different ways, depending upon the class and available time:

Option A. Students work individually, all on the same general site (e.g., Copernicus, Marius Hills, etc.).

Option B. Students work individually, each on a different general site.

Option C. Students work in groups of 3 to 5, all on the same general site.

Option D. Students work in groups of 3 to 5, each group on a different general site.

3. Regardless of option selected, the assignment could be made for either outside work or as lab work for two or three lab periods.

4. If time permits, the last lab session could be used for the presentation of various sites selected, during which the site and scientific rationale of the selection could be defended and debated as an open forum.

5. The main part of the exercise should be the photogeologic analysis and mapping, from which the specific landing site and geological traverses are derived. The listing of the "capabilities" of the Orbiting CM-SM and the surface experiments are secondary to the photogeology. The inclusion of this material is twofold: *first*, it requires the student to gain some understanding of remote sensing techniques and geophysical instruments, and *second*, the type of geological data that can be gained with the various instruments (heat flow, subsurface structure, etc.) will influence the site selection.

Student level and capability as well as available time will determine the emphasis placed on the "non-photogeologic" aspects of the exercise.

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6. Candidate sites are presented in the material that follows. These are some of the general sites that were considered during the Apollo program as potential landing areas. For each site, lists are given for available maps and photographs. Material best suited for the exercise is indicated with an asterisk and the best photographs are reproduced. Photographs can be obtained at cost from the National Space Science Data Center and maps from the Superintendent of Documents.

7. Site material for each student or group should consist of:

A. U.S.G.S. Geological Map, 1:1,000,000, covering the general area.

B. LAC 1:1,000,000 charts for general area.

C. Base Map or Lunar Orbiter Photograph. Students prepare their geologic map, landing site, and geological traverses on this base, using tracing paper.

D. Reference photos and maps (other Orbiter and Apollo photos, etc.).

8. An abbreviated and modified form of this exercise could be given as a final examination (probably a "take-home" examination).

Planetary Geology

APOLLO LANDING SITE EXERCISE

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I. OBJECTIVES

To select an Apollo landing site by applying your current knowledge of lunar geology to the analysis of lunar data, photographs, and maps.

II. MATERIALS

Sets of photographs, lunar charts, 1:1,000,000 geological map(s) and reference material.

III. HYPOTHETICAL SITUATION

Assume that there have been only three lunar landings (Apollo 11, 12, and 14) and that there is to be only one more landing – the one that you are to plan. You must select the site and plan the mission to derive maximum geological data and to solve as many lunar problems as possible.

IV. CAPABILITIES

(See reference material for instrument descriptions.)

A. *Orbiting CM-SM (Command module – service module) will have the following instruments*:

Gamma-ray spectrometer, X-ray spectrometer, mass spectrometer, infrared scanning spectrometer, lunar sounder, panoramic camera, mapping camera.

B. *Lunar module (LM)*

1. ALSEP (Apollo lunar surface experiment package): lunar active and passive seismometers, lunar heat flow, triaxis magnetometer, lunar atmosphere composition.

2. Other experiments: geology investigation, surface electrical properties.

3. Lunar rover: 3 EVA (extravehicular activity) traverses, each cannot be more than 10 km long, round trip.

C. *Engineering constraints*:

The Apollo spacecraft travels in an inclined equatorial orbit from east to west. The LM separates from the CM-SM and begins its descent hundreds of miles from the landing site,

bringing the LM into the site on a very low approach angle. The astronauts must have a clear view of the landing site during approach. Therefore, the landing site must not have high, steep mountains on its east side. The site must be fairly smooth, level, and free of large boulders.

V. REQUIREMENT

Under the conditions described above, you are to prepare a report, "Geological Analysis of Apollo Landing Site." The report should consist of the following parts:

A. *Objective.*

A simple statement of the mission objective(s). What specific lunar problems potentially could be solved?

B. *Regional Geology.*

Describe the broad geologic, physiographic and structural setting of the area.

C. *Site Selection.*

Select the exact landing site within the general area indicated. Use the clear plastic sheet with the 10 km diameter circle (range of the Lunar Rover) to select the best site.

D. *Site Geology.*

Describe the local geology of the site (physiography, stratigraphy, structure). Prepare a detailed geologic map showing landing site.

E. *Detailed Plan.*

Devise 3 Rover EVA's (10 km round trip) and 2 foot EVA's (1.5 km round trip) on the site map. Describe the specific objectives of each EVA, show stations along each traverse and discuss the duties to be carried out for each station.

F. *Summary.*

Which of the following geological, geochemical and geophysical problems will this site potentially solve:

1. Chronology
    a. "Original crust"
    b. Origin of major mare basins
    c. Mare flooding
    d. Post-mare time scale

2. Composition
    a. "Primitive" rocks
    b. Deep-seated rocks

c. Differentiated rocks
d. Transient events
e. Atmosphere

3. Processes
   a. Cratering
      (1) Impact
      (2) Volcanic
      (3) Chain
   b. Transport
      (1) Ejecta
      (2) Gravity
   c. Volcanic-Tectonics
      (1) Fault
      (2) Dome
      (3) Flows
      (4) Rilles
      (5) Ridges
      (6) Seismicity

COPERNICUS

Geological Description

Copernicus (9°52'N, 19°55'W) is a relatively young, very large bright-rayed probable impact crater approximately 95 km in diameter and located south of Mare Imbrium. The primary objective of the mission to the floor of the crater, 4 km below the crater rim is the examination of the central peaks and the crater floor material. The central peaks (800 meters high) probably are composed of deep-seated material. Samples from the central peaks could aid in determining the internal characteristics of the moon. Examination of the domes and textured material of the crater floor could provide an understanding of the process of crater floor filling and help to clarify the role of volcanism in post-impact crater modification. Age determinations of the central peak material, the cratering event, and the subsequent crater fill material will aid in understanding the origin and modification of large impact craters.

Scientific Objectives

1. Sampling the central peaks materials with emphasis on variations in texture or appearance.
2. Study the structures within the central peaks and the relationships between the peaks and floor materials.
3. Sample the floor materials.
4. Sample and study domical hills within the floor.
5. Emplace geophysical instruments and monitering experiments of the distant wall terraces.

Reference Material

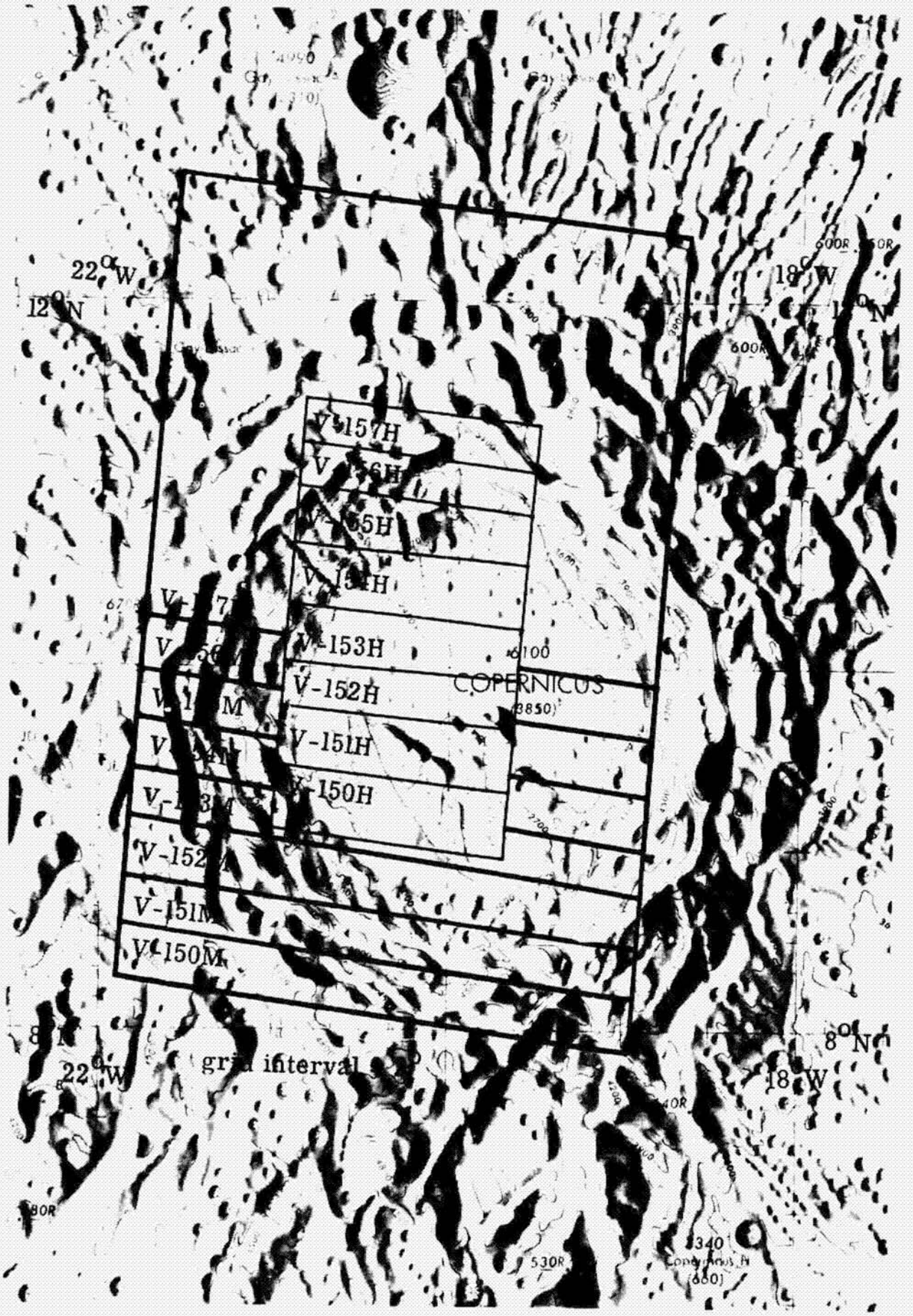
Photography:

Mission	Frame Number
Orbiter II	M, H-162 (oblique)
Orbiter IV	H-121 (2/3)
	-121 (1/3)
	-126 (2/3)
	-126 (1/3)
Orbiter V	M, H-150
	-151
	-152
	-153
	-154
	-155
	-156
	-157

Mission	Magazine	Frames	Film Size
Apollo 12	Q	7535	70 mm
Apollo 12	Q	7541	70 mm

Cartography:

Type Map	Item	Scale
Topographic	LAC 58	1,000,000
Geological	Copernicus (LAC 58) H. H. Schmitt, N. J. Trask and E. M. Shoemaker, 1967. USGS Map I-515	1,000,000
Photomosaic	Copernicus V-37	200,000
TOPOCOM	Orb V-37 (200)	


22°W
12°N
18°W
8°N
V-157H
V-154H
V-153H
V-152H
V-151H
V-150H
V-151M
V-150M
COPERNICUS
(3850)
grid interval

Site V–37.

CRATER COPERNICUS
LO II H-162 3/3

CRATER COPERNICUS
LO V SITE 57 M-151
NORTH

MARIUS HILLS

Geological Description

The Marius Hills (14°36'N, 56°34'W) are a series of domes, cones and rilles of Eratosthenian material located northwest of the crater Marius near the center of Oceanus Procellarum. The morphologic units which comprise these hills are analogous in form and sequence to terrestrial volcanic complexes which display a wide spectrum of rock compositions and ages. The various geologic units suggest that a prolonged period of volcanic activity has occurred in the Marius Hills area and that magmatic differentiation has produced a spectrum of rock types and a series of volcanic landforms displaying characteristic structural relationships. Therefore, the primary objectives of a mission to the Marius Hills are to study the geologic units in order to establish the extent and age of possible magmatic differentiation and to determine the structural relationships of volcanic landforms in the maria.

Scientific Objectives

1. Sampling the variety of volcanic domes and cones present in the area to collect evidence for differentiation of lunar materials and its extent.
2. Sampling and studying the structures of the mare (wrinkle) ridges, sinuous rilles, and rimless depressions in the area.
3. Sampling the plateau plains material.
4. Emplacing and conducting geophysical experiments.
5. Obtaining high resolution photography on this high inclination mission of the western part of the moon's nearside.

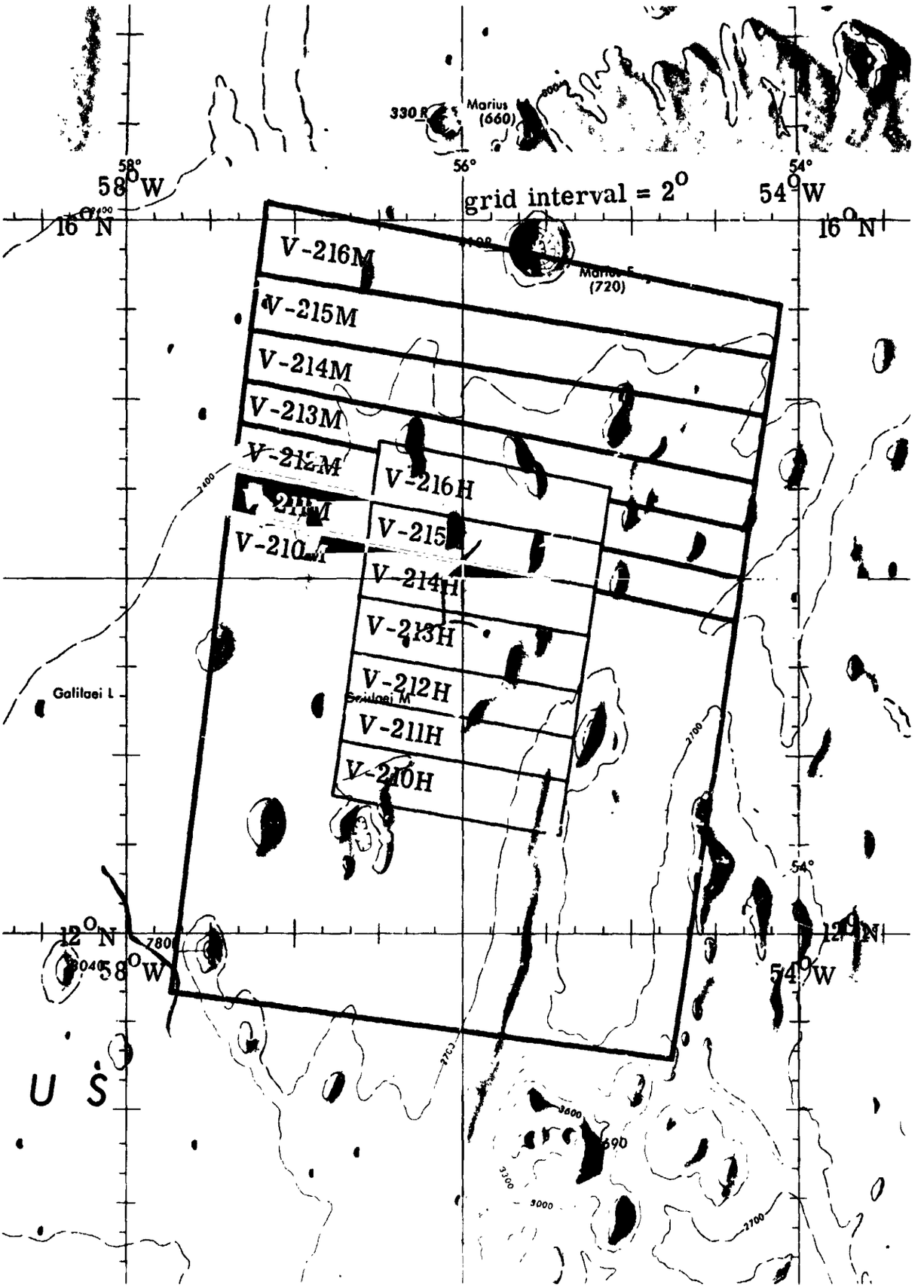
Reference Material

Photography:

Mission	Frame Number
Orbiter IV	M-150 (2/3)
Orbiter IV	M-157 (2/3)
Orbiter V	M, H-210
↓	H-211
	H-212
	H-213
	H-214
	H-215
	H-216
	H-217

Cartography:

Type Map	Item	Scale
Topographic	LAC 56	1,000,000
Geologic	Hevelius (LAC-56) J. F. McCauley, 1967 USGS Map I-491	1,000,000
Photomosaic TOPOCOM	Marius F (V51)	1:250,000


grid interval = 2°
58° W
54° W
16° N
12° N
V-216M
V-215M
V-214M
V-213M
V-216H
V-215H
V-214H
V-213H
V-212H
V-211H
V-210H
Marius
(660)
(720)
Galilaei L
Galilaei M
U S

Site V-51.

MARIUS HILLS
LO V SITE 51 M-214
NORTH

HYGINUS RILLE

Geological Description

The crater Hyginus (8°08'N, 6°24'E) is located south-southeast of Mare Vaporum at the juncture of the two branches of the Hyginus linear rille. The crater is 10 km in diameter and is characterized by a very low rim and numerous domical hills on the crater floor. Two linear rille branches of *Rima Hyginus* trend northwest and east and are characterized by associated chains of low-rimmed craters. *Rima Hyginus* appears to be a structural graben, formed in Imbrium plains-forming units. The northwest rille segment is in the Cayley Formation. Smooth plains-forming units surrounding Hyginus Crater may be of volcanic origin and closely related to the origin of the crater. The eastern rille segment is in a widespread upland plains-forming unit (possibly Cayley) whose origin is not well understood. The craters associated with Hyginus rille are morphologically similar to terrestrial volcanic craters known as maars. On Earth, deposits associated with this type of volcanic crater often contain samples brought up from deep within the mantle. The primary objectives at this landing site are the sampling of possible deep-seated material and the plains-forming material in the vicinity of Hyginus crater and rille.

Scientific Objectives

1. Sampling the ejecta fields of the crater Hyginus or the associated lobate crater.
2. Sampling the ejecta fields of the crater chains associated with Rima Hyginus in search for xenoliths or deep-seated rock fragments.
3. Sampling the plains-forming (Cayley Formation) materials in the vicinity.
4. Studying the structures along the walls of Rima Hyginus in search for layering or banding.
5. Emplacing geophysical experiments.

Reference Material

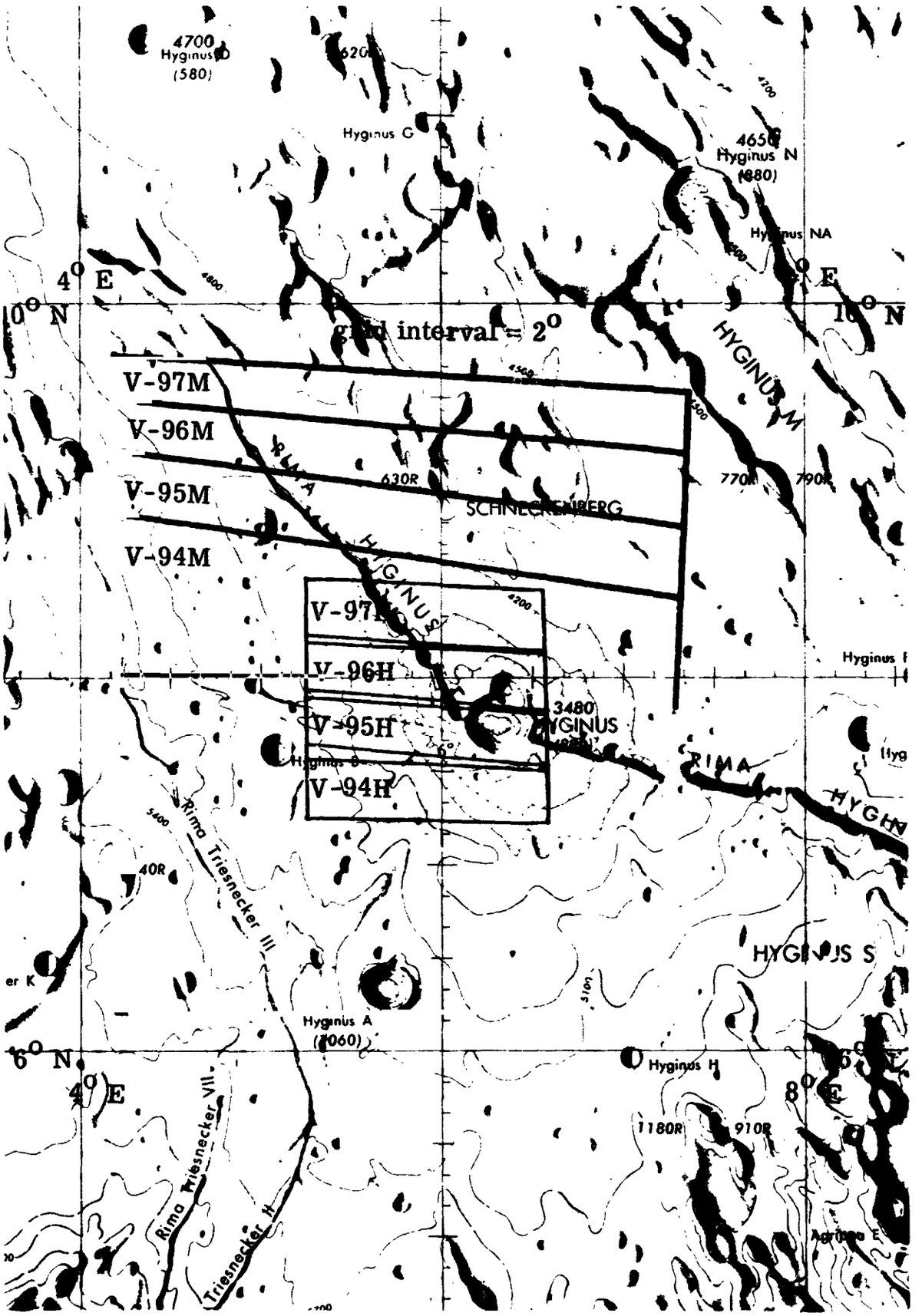
Photography:

Mission	Magazine	Frame Number
Orbiter III		H-73 (oblique)
Orbiter IV		-97 (2/3)
		-97 (3/3)
		-102 (2/3)
		-102 (3/3)
Orbiter V		M and H-94
		-95
		-96
		-97
Apollo 10	S	4811* (oblique)
↓	S	4813 ↓
	R	4648
	R	4649
	R	4650
	R	4651*
	R	4652

*Recommended

Cartography:

Type Map	Item	Scale
Topographic	LAC 59	1,000,000
Topographic	AIC 59B	500,000
Topographic	AIC 59C	500,000
Geologic	Mare Vaporum (LAC 59) D. Wilhelms, 1968 USGS Map I-548	1,000,000
Photomosaic	Rima Hyginus (V-23.1)	200,000
Topocom		
Photomap	Rima Hyginus	250,000
Topocom		


4700
Hyginus D
(580)
Hyginus G
4650
Hyginus N
(880)
Hyginus NA
4° E
0° N
grid interval = 2°
V-97M
V-96M
V-95M
V-94M
RIMA HYGINUS
630R
SCHINEEBERG
770R
790R
HYGINUS M
V-97H
V-96H
V-95H
V-94H
3480
HYGINUS
Hyginus F
Hyginus B
RIMA
HYGINUS
Rima Triesnecker III
40R
HYGINUS S
Hyginus A
(1060)
6° N
4° E
Hyginus H
8° E
1180R
910R
Rima Triesnecker VII
Triesnecker H

Site V–23.1.

RIMA HYGINUS
LO V SITE 25.1 M-46

TYCHO

Geological Description

Crater Tycho (40°56'S, 11°15'W) is a very young impact crater 85 km in diameter in the southern lunar highlands. Bright rays from Tycho spread across the near side of the Moon. A mission to the northern crater rim of Tycho would land in the vicinity of the Surveyor VII spacecraft. Principal mission objectives include investigation of highland composition and of features associated with a young large impact crater. The origin and nature of the ejecta, flows, and associated volcanism located on the crater rim are of interest in this regard. Since Tycho is approximately 4 km deep, the ejecta material should provide samples from deep within the highlands. The composition and age of this material will provide important information about the formation and evolution of the lunar highlands. Establishment of the age of the relatively young event which produced Tycho will add an important point to the lunar time scale.

Geological Description

Scientific Objectives

1. To sample the highland material excavated and ejected by the impact event that created the crater Tycho.
2. To sample and study the post-impact flows and ponds of dark material.
3. To study and sample the Surveyor VII Spacecraft and its vicinity including the rocks it analyzed and the trenches it dug.
4. To emplace geophysical instruments.
5. To obtain metric and high resolution photography on this high inclination orbit mission to the "southern highlands."

Reference Material

Photography:

Mission	Frame Number
Orbiter IV	H-119 (2/3)
	-124 (2/3)
Orbiter V	M, H-125
	-126
	-127
	-128+

Cartography:

Type Map	Item	Scale	Type Copy
Topographic	LAC-112	1,000,000	Litho

16° W
38° S
V-128
V-127M
V-126M
V-125
V-128H
V-127H
V-126H
V-125H
grid interval = 2
46° S
16° W

Site V–30.

CRATER TYCHO
LO V SITE 30 M-126
NORTH

CRATER TYCHO
LO V SITE 301 H-127 1/3
NORTH

HADLEY-APENNINES

Geological Description

Rima Hadley (24°57′N, 2°27′E) is a V-shaped lunar sinuous rille which parallels the Apennine Mountain front along the eastern boundary of Mare Imbrium. The rille is in mare material of Eratosthenian age. The rille apparently originates in an elongate depression in an area of associated volcanic domes and generally maintains a width of about 1 km and a depth of 200 meters until it merges 100 km to the north with a second rille of apparent structural origin. The origin of sinuous rilles such as Rima Hadley is enigmatic but is probably due to some type of fluid flow. The Apennine Mountains rise up to 2 km from the area of Rima Hadley and probably contain ancient material exposed during the excavation of the Imbrium basin. The determination of the nature and origin of a sinuous rille and its associated elongate depression and deposits will provide information on an important lunar surface process and may yield data on the history of lunar volatiles. Sampling of Apenninian material should provide very ancient rocks whose origin predates the formation and filling of the major mare basins.

Scientific Objectives

1. Sampling the pre-Imbrium materials of the Apennine Mountain front and studying the structures and textures displayed.
2. Sampling and studying the material within the sinuous rille (Rima Hadley).
3. Sampling the material surrounding the Hadley C crater for clues of its origin.
4. Sampling the mare material of Palus Putredinis for comparison with other mare samples.
5. Emplacing and conducting geophysical experiments and atmosphere detection devices.

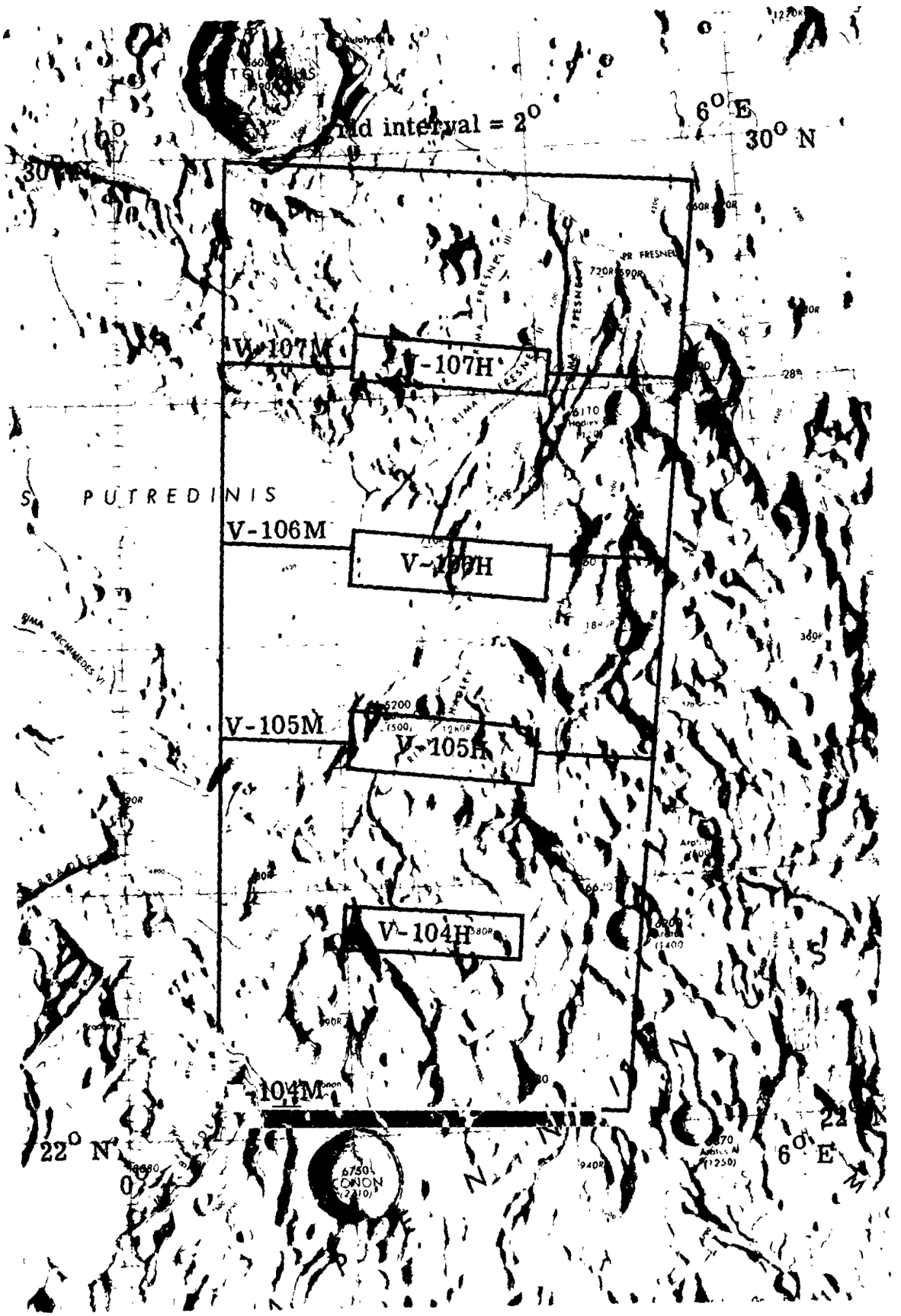
Reference Material

Photography:

Mission		Frame Number
Orbiter IV		H-102 (3/3)
		-103 (1/3)
		-109 (3/3)
		-110 (1/3)
Orbiter V		M-H-104
		-105
		-106
		-107
		Stereo Pan Frames
Apollo 15	Rev 27	9425 and 9430
		9427 9432
		9429 9434
		9431 9436

Cartography:

Type Map	Item	Scale
Topographic	LAC-41	1,000,000
Geologic	Montes Apenninus Region (41) R. J. Hackman, 1966 USGS Map I-463	1,000,000
Geologic	Apennine-Hadley Region Apollo 15 pre-mission M. H. Carr, K. A. Howard, F. El-Baz, 1971 USGS Map I-723	
Photomosaic	Rima Hadley (V26.1b)	200,000
TOPOCOM Topographic Orthophotomap NASA	Hadley	250,000


Grid interval = 2°
6° E
30° N
V-107M
V-107H
PUTREDINIS
V-106M
V-106H
V-105M
V-105H
V-104H
104M
22° N
6° E

Site V-26.1.

RIM* HADLEY
LO V SITE 26.1 M-105
NORTH